Atmospheric Measurements and the Indirect Climatic Effects of Aerosols

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LONG-TERM GOALS

The long-term goal of this project is to gain a deep understanding of the role of atmospheric aerosols in affecting transmission of radiation through the atmosphere and in altering cloud properties and global climate.

OBJECTIVES

The scientific objectives of this project are to identify the specific manner in which atmospheric aerosols determine cloud properties. The technological objectives are to develop state-of-the-art instruments for aircraft sampling of aerosols that advance the long-term goals of the project.

APPROACH

The main technical approach is to conduct aircraft studies of the atmosphere, in which comprehensive sampling of atmospheric particles and radiative and cloud properties is carried out. The aircraft studies are complemented by laboratory investigations and theoretical analysis. Key individuals participating in this work are Professors John H. Seinfeld and Richard C. Flagan at the California Institute of Technology and Dr. Haf Jonsson at Naval Postgraduate School. Professor Seinfeld serves as Principal Investigator. Professor Flagan plays a key role in instrumentation development and planning of aircraft operations. As Chief Scientist of CIRPAS, Dr. Jonsson oversees all aspects of aircraft measurements and data management.

WORK COMPLETED

During the past year, the work completed consists of the following:
1. Analysis of data from CRYSTAL-FACE field experiment (Key West, FL, June – July 2002)
2. Conducting CSTRIPE field experiment (Monterey CA, July 2003)

RESULTS

CRYSTAL-FACE Field Experiment – CRYSTAL-FACE (http://cloud1.arc.nasa.gov/crystalface/) was conducted in continental and marine environments near southern Florida in July 2002. Detailed profiles of thirteen cumulus clouds were made by the CIRPAS Twin Otter aircraft, which was equipped with four aerosol sizing systems, two CCN counters operated at 0.4% and 0.7% supersaturation, an Aerodyne aerosol mass spectrometer, a MOUDI filter sampler system, two cloud drop sizing probes, and two turbulence probes. A wide range of CCN (300 to >3500 cm^{-3}) and cloud

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drop concentrations (200 to >1600 cm^{-3}) provided an ideal case study for aerosol-cloud interactions. Vertical characterization of the young and mature cumulus clouds were obtained from multiple horizontal passes from below cloud base to cloud top. The payload on the CIRPAS Twin Otter included instrumentation for an aerosol/CCN closure study. Throughout the mission, the ambient aerosol was measured simultaneously by the Caltech CCN Counter, the DACADS instrument, which measures the aerosol size distribution, and the Aerodyne Aerosol Mass Spectrometer (AMS), which provides detailed chemical information for larger particles. The data from the AMS indicated that in most circumstances the aerosol was primarily ammonium sulfate; assuming this composition allows a comparison between the measured CCN concentration and a predicted concentration based on the aerosol size distribution. To make this comparison, the CCN concentration was averaged for the duration of a single scan of the dry aerosol size distribution from the DACADS instrument. This result was compared to the concentration of particles above a given cut size; this cut size varied slightly over the course of the mission, but could be accurately predicted using a model that simulated instrument performance using in-flight housekeeping data (Van Reken et al., 2003).

A closure study between aerosol and warm-cloud microphysics was performed using field data collected during the campaign (Figure 1). These data provide excellent constraints for studies using large-eddy-simulation models to understand the effect of aerosols on cloud albedo, cloud lifetime, and precipitation formation in warm cumulus. Likewise, these Twin Otter data play a key role in the larger CRYSTAL-FACE program objectives (which included six aircraft and two surface stations) by providing insight into the influence of aerosol/warm cloud interactions on large-scale convective processes, such as ice nucleation, mixed phase processes, cirrus albedo, and the thermodynamic forcing of large cumulus systems.

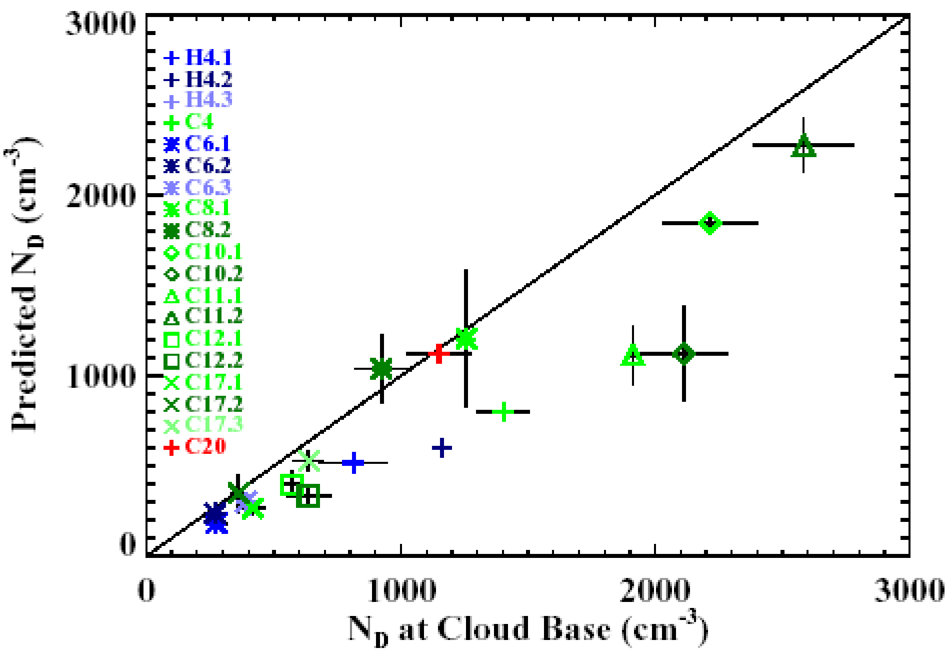

Figure 1.
[A detailed cloud parcel model is tested against observations of cloud droplet concentration collected by the CIRPAS Twin Otter during the NASA CRYSTAL-FACE campaign, conducted in July, 2002. The model takes as input the concentration, size distribution, and composition of the aerosol observed beneath the cloud, and predicts the number of droplets that activate, assuming adiabatic ascent at the updraft velocity simultaneously observed by the Otter's gust probe. In adiabatic cloud regions, droplet concentration is, on average, adequately predicted by the model. In this way, a comprehensive closure study has been conducted on the cloud activation process using measurements obtained from a single platform. In this closure, however, there is significant variability in the observed droplet concentrations that is not predicted by the model. When data are further restricted to those observations having the smallest variations in liquid water content and the smallest droplet dispersions, (to isolate recently activated cloud parcels) the observations of droplet concentration generally exceed the model predictions. These biases cannot be explained with observed variations in aerosol concentration or updraft velocity, indicating that some other effects or measurement bias may be responsible for the discrepancy. Bias in the optical probes and the updraft velocity measurement has been investigated, and – while such biases cannot be ruled out – no systematic artifact has been identified of the magnitude necessary to explain the model-observation discrepancy. Further investigation using data collected from the Aerosol Mass Spectrometer may indicate whether the discrepancies might be chemical in nature.]

CSTRIPE Field Experiment - CSTRIPE was a field experiment designed to quantify the effect aerosol has on the microphysics, precipitation and dynamics of marine stratocumulus (MSc). The CIRPAS Twin Otter aircraft was deployed in a one month mission off the coast of Monterey, California in July 2003. The strategy was a blend from two previous field experiments, MAST and ACE-2 that were directed towards aerosol-MSc interactions. MAST (Monterey Area Ship Track Experiment) was successful in that it targeted ship tracks (Durkee et al., 2000). Use of a localized aerosol perturbation, such as ship tracks, obviates the difficulty of separating aerosol-forced signals from meteorologically

forced signals. ACE-2 (The Second Aerosol Characterization Experiment) was successful in that it used a number of well articulated closure studies to evaluate state-of-the-art models including: hygroscopic and CCN activity of aerosol (Chuang et al., 2000); cloud activation (Guibert et al., 2003; Snider et al., 2003); the effect of entrainment mixing on the vertical and horizontal distribution of cloud microphysics; and the link between cloud microphysics and the radiative properties of the clouds (i.e. both albedo and bidirectional reflectance used by satellites to retrieve cloud optical properties) (Brenguier et al., 2003). Data analysis from CSTRIPE is just beginning at this time.

IMPACT/APPLICATIONS

The potential future impact of this project is to reduce the uncertainty in understanding the role of aerosols in determining climate in the marine atmosphere and in estimating the future effects of anthropogenic and natural atmospheric aerosols on the Earth's climate.

TRANSITIONS

A major future transition will be the use of instrumentation, such as the CCN instrument, developed in this project by others.

RELATED PROJECTS

A closely related project is the full CRYSTAL-FACE experiment, in which we participated. The appropriate web site is: http://cloud1.arc.nasa.gov/crystalface.

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PATENTS

None

HONORS/AWARDS/PRIZES

Professor Seinfeld received honorary doctorates in 2002 from the University of Patras (Greece) and Carnegie Mellon University. He received the Haagen-Smit Clean Air Award from the State of California Air Resources Board in 2003.